NPS-MA-94-003

NAVAL POSTGRADUATE SCHOOL

Monterey, California

BENEFIT OF SOUND CUEING IN COMBAT SIMULATION

by

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Technical Report For Period
July 1993 - October 1993

Approved for public release; distribution unlimited

Prepared for: Naval Postgraduate School
Monterey, CA 93943

NAVAL POSTGRADUATE SCHOOL
MONTEREY, CA 93943

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This report was prepared in conjunction with research conducted for the Naval Postgraduate School and funded by the Naval Postgraduate School.

This report was prepared by:

Unclassified
SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

Form Approved OMB No 0704-0188

1a REPORT SECURITY CLASSIFICATION Unclassified	1b RESTRICTIVE MARKINGS
2a SECURITY CLASSIFICATION AUTHORITY	3 DISTRIBUTION / AVAILABILITY OF REPORT Approved for public release; distribution unlimited
2b DECLASSIFICATION / DOWNGRADING SCHEDULE	
4 PERFORMING ORGANIZATION REPORT NUMBER(S) NPS-MA-94-003	5 MONITORING ORGANIZATION REPORT NUMBER(S) NPS-MA-94-003
6a NAME OF PERFORMING ORGANIZATION Naval Postgraduate School 6b OFFICE SYMBOL (If applicable) MA	7a NAME OF MONITORING ORGANIZATION Naval Postgraduate School
6c ADDRESS (City, State, and ZIP Code) Monterey, CA 93943	7b ADDRESS (City, State, and ZIP Code) Monterey, CA 93943
8a NAME OF FUNDING / SPONSORING ORGANIZATION Naval Postgraduate School 8b OFFICE SYMBOL (If applicable) MA	9 PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER OM,N
8c ADDRESS (City, State, and ZIP Code) Monterey, CA 93943	10 SOURCE OF FUNDING NUMBERS PROGRAM ELEMENT NO / PROJECT NO / TASK NO / WORK UNIT ACCESSION NO

11 TITLE (Include Security Classification)
Benefit of Sound Cueing in Combat Simulation

12 PERSONAL AUTHOR(S)
Beny Neta, Bard Mansager

13a TYPE OF REPORT	13b TIME COVERED	14 DATE OF REPORT (Year, Month, Day)	15 PAGE COUNT
Technical	FROM 7-93 TO 10-93	15 Oct 93	13

16 SUPPLEMENTARY NOTATION

17 COSATI CODES			18 SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
FIELD	GROUP	SUB-GROUP	Janus(A) combat simulation model, TUGV

19 ABSTRACT (Continue on reverse if necessary and identify by block number)

Here we report on the incorporation of a sound algorithm into Janus(A) combat simulation mode and the inclusion of the Tactical Unmanned Ground Vehicle (TUGV) for sound acquisition. The benefi of TUGV will be demonstrated and some ideas for model improvements will be given.

20 DISTRIBUTION / AVAILABILITY OF ABSTRACT ☒ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT ☐ DTIC USERS	21 ABSTRACT SECURITY CLASSIFICATION Unclassified
22a NAME OF RESPONSIBLE INDIVIDUAL Beny Neta	22b TELEPHONE (Include Area Code) 408-656-2782 / 22c OFFICE SYMBOL MA/Nd

DD Form 1473, JUN 86 Previous editions are obsolete SECURITY CLASSIFICATION OF THIS PAGE

S/N 0102-LF-014-6603

Benefit of Sound Cueing in Combat Simulation

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5 October 1993

1 Introduction

Audio information concerning targets generally includes direction, frequencies and energy levels. One use of audio cueing is to use direction information to help determine where more sensitive visual detection and acquisition sensors should be directed. Generally, use of audio cueing will shorten times required for visual detection, although there could be circumstances where the audio information is misleading and degrades visual performance. Audio signatures can also be useful for helping classify the emanating platform, as well as to provide estimates of its velocity.

The Janus combat simulation is the premier high resolution model used by the Army and other agencies to conduct research. This model has a visual detection model which essentially incorporates algorithms as described by Hartman [3]. The model in its current form does not have any sound cueing capabilities. We have modified Janus combat simulation model to include the Tactical Unmanned Ground Vehicle (TUGV) for sound acquisition. The new model also allows sound to be played by using a subroutine ACOUSDET2 developed by TRAC White Sands (Watson [9]).

In the next section we discuss visual detection and define the terminology. Section 3 will be devoted to an aural detection algorithm used in UCCATS. We suggest several modifications to this algorithm in Section 4. In section 5 we described the TUGV. The sound algorithm we incorporated in Janus will be described in Section 6. We conclude with remarks concerning the performance of the algorithm and suggestions for further improvements.

2 Visual Detection

The target acquisition combat process has been investigated for many years. Work on the physiology and psychophysics of vision began in the last century and continues today, (see J. K. Hartman, [3]). The seminal study of military target acquisition is the work "Search and Screening" by B. O. Koopman [4]. Almost all later work in modeling of target acquisition builds on the basic ideas of this report. Koopman defined detection as, "that event constituted by the observer's becoming aware of the presence and possibly of the position and even in some cases of the motion of the target". There are several levels of target acquisition (see e.g. Hartman, [3].

Cueing Information provides the approximate location for further search (e.g. a gun flash or a noise).

Detection means that an observer decides that an object in his field of view has military interest (e.g. he distinguishes between a vehicle and a shrub).

Classification means that the observer is able to distinguish broad target categories (e.g. tracked versus wheeled vehicles).

Recognition means discrimination among finer classes of targets (e.g. tank versus armored personnel carrier).

Identification provides precise target identity.

Note that detection is used both to denote the entire target acquisition process (Koopman's definition) and as a level of acquisition. The intended meaning will be specified if it is not clear from the context.

The response to a target acquisition depends on the level of acquisition. Detection may cause the observer to look more closely or to use better sensors in order to identify the target.

Target acquisition is very complex and requires research in many areas, such as Physics, Meteorology, Electronics, Physiology and Psychology.

Hartman discusses several models of target acquisition using real time imaging sensors such as unaided vision, optically aided vision, and infrared scopes. All of these sensors present an image to the human observer, and target acquisition requires that the observer respond to the image displayed. There are also models for non-imaging sensors such as radar and sonar.

Koopman observed two significant characteristics of the visual detection phenomenon:

i. There is a certain set of physical requirements which must be met for detection, for example, line-of-sight to the target must exist; the target signature must be greater than the sensor threshold; the sensor must be pointing in the right direction.

ii. "Even when the physical conditions make detection possible, it wil by no means inevitably occur". Thus detection models are stochastic. Examples of factors important in target acquisition are: target type, target fraction exposed, target movement, observed background complexity, atmospheric visibility, sensor device, sensor calibration and maintenance, observer training, observer alertness, observer motivation and many more.

3 Aural Detection

One of the limitations of visual detection is the necessity of existence of line-of-sight to the target. Military platforms can be noisy, especially when they are moving. If the movement is on the other side of a hill or, in urban setting, obscured by buildings, an aural detection algorithm can be useful. It is, of course, to be used in conjunction with visual detection. For example, the noise eminated by a military platform can give cueing information. The detection and classification can be done by recognizing the type of noise heard. For example rotary wing aircraft can be distinguished from wheeled or tracked vehicle. Other characteristics such as sound pressure level can help in classification.

Cueing information obtained by sound will be given to observers so they may point their video sensors in that direction.

The only available algorithm for aural acquisition known to us can be found in UCCATS. In the following we describe that algorithm. We conclude the report with our modifications to it and with ideas for future research.

The Conflict Simulation Laboratory at Lawrence Livermore has developed sound cueing as a part of the Urban Combat Computer Assisted Training System (UCCATS). We now describe this model as it is given in The UCCATS Algorithms Manual (see S. Wong, [10]).

UCCATS attempts to simulate the detection of mechanical vehicles based on sound cueing. Sound cueing is determined by the mechanical vehicle and the distance between the vehicle and the detecting unit. Units report the detection of mechanical vehicles to the player. UCCATS provides the player the capability to turn the reporting of units detected by sound on or off.

The sound cueing model computes the perceived sound level for a given listener based on the inherent sound level of the platform and its distance from the listener. The attenuation of the generated sound level of the platform depends only on distance.

Other assumptions and dependencies associated with sound cueing are:

i. Each listener can be surrounded by sound wherever it goes. For example, a human driving a truck will always be surrounded with the noise generated by the truck. We would say that the listener is surrounded by an inherent sound that is generated at an inherent sound level. In the UCCATS simulation the inherent sound level of each platform takes on one of two values depending on whether or not the listener is moving.

ii. The only sound that can mask the sound of an enemy platform is that inherent sound that surrounds the listener. This implies that the listener mounted on the noisiest platform will not be able to hear any other platform.

iii. Each platform is considered in isolation. For example, an thousand tanks moving between a listener and a truck will not mask the sound of the truck.

iv. Listening has no blind spots, i.e. any platform close enough to the listener may be heard.

v. Listeners can only hear platforms that do not belong to the same side as the listener. This fits in well with the notion that the units on the same side know exactly where each other are at.

vi. A unit will not report hearing any platform that it has already acquired.

vii. When a unit hears something that should be reported. the simulation causes the listener's symbol to blink to alert the work station operator.

viii. Each increase of 10 db in the intensity of a sound stimulus, no matter what the frequency component, doubles the sensation of the loudness.

ix. The propagation of sound is modeled as a wave front that expands in a spherical fashion from the platform with the pressure varying inversely proportional to the volume of the sphere with the given radius".

4 Modified Aural Acquisition Algorithm

The aural acquisition algorithm in UCCATS is clearly a simple model. a demonstration of which can be seen at Lawrence Livermore National Laboratory. There are many possible modifications to be considered. Some of these are simple enough and can be included in an implementation of sound cueing in JANUS. The others will lead to a deterioration of the response time and will not be possible to include unless a version of JANUS for a parallel computer is developed.

The following can be incorporated in a version of JANUS on serial computers:

i. Eliminate the third assumption in the sound cueing algorithm implemented in UCCATS. Thus the noise generated by platform near the listener will be incorporated with the inherent sound level of the listener.

ii. Add an assumption that noise resulting from shooting in a proximity of a listener must also be incorporated in the inherent sound level.

iii. Another platform should be modelled in JANUS, this is a listening - capable unit called TUGV (Tactical Unmanned Ground Vehicle). This unit is now under development.

In the next section we describe, in some detail, the physical and performance characteristics of the platform and sensory modules of the TUGV.

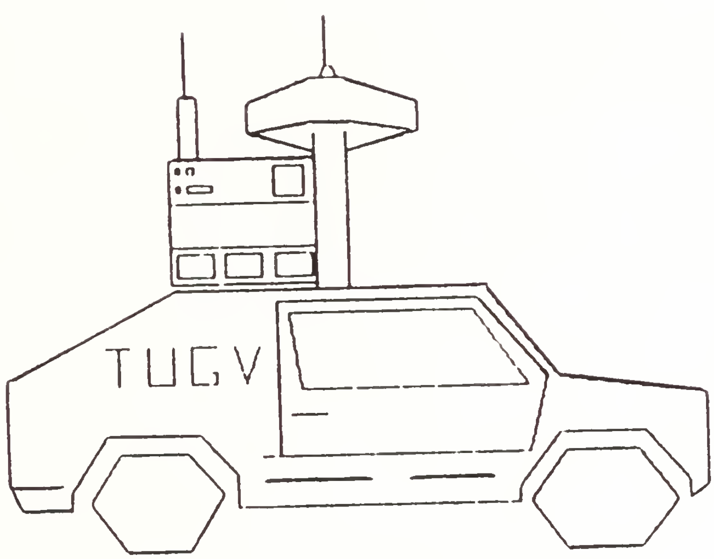

Figure 1: TUGV

Table 1: TUGV Model

PHYSICAL DIMENSIONS OF THE TUGV MODEL	
Vehicle Width	118" (300 cm)
Vehicle Height	157"(400 cm)
Wheel Width	11.8" (30 cm)
Belly Width	96.5" (245 cm)
Engine Type	Diesel
Fuel Capacity	200 Gallons
Magnetic Shadow Width	106" (270 cm)
Minimum Detection Demension	7.87" (20 cm)

Table 2: TUGV Model

PERFORMANCE CHARACTERISTICS OF THE TUGV MODEL	
Maximum Speed	15.5 mph (25 Km/hour)
Fuel Consumption:	
Stationary	2 Gallons/hour
Moving	10 Gallons/hour

5 TUGV

In this section we describe the TUGV. The data is based on the most current information available. Figure 1 is the icon which represents the TUGV in the Janus (A) model (see Proctor [6]) as viewed from the terminal monitor.

In Table 1, we give the physical dimensions of the TUGV. The assumption of a four-meter-height of the TUGV was required in order to accurately depict the height of the sensory module extended. When the TUGV is in an acquisition mode, the sensory module is elevated to 14 feet above the ground. The minimum detection dimension is assumed to be 0.2 meters, since approximately 80% of the sensory module (1 meter) will be concealed by either natural or man made comoflague.

The performance characteristics of the TUGV are given in Table 2.

The representation of the sensory module presented problems in the modelling effort. The current version of Janus (A) only allows a primary and an alternate sensor to be added to a vehicle. The prototype TUGV has three sensors, thermal, optical and acoustic, operating concurrently and independently. The model described in the next section has an acoustic sensor which was acquired from the Janus (A) Gaming Division at White Sands, NM. The acoustic sensor can be turned on and off and does not function if the vehicle is in defilade. If the acoustic sensor is off then the primary sensor is an optical sight with a thermal sensor as an alternate. In the following tables 3-4 we give the specification of the optical and thermal sensors

Table 3: Sensory Module

SENSORY PLATFORM CHARACTERISTICS OF TUGV MODEL	
Primary Sensor:	
Type	Optical
Field of View	14.5 Degree Horizontal
Alternate Sensor:	
Type	Thermal
Field of View	5 Degree Horizontal
Maximum Range of Sensors	2000 Meters
Laser Designator	Included in sensory module
Acoustic Sensor	Included in sensory module

Table 4: Optical/Thermal Sight

OPTICAL SIGHT SPECIFICATIONS FOR TUGV MODEL	
Narrow Field of View	6.5 Degrees
Wide Field of View	6.5 Degrees
Cycles per Milliradian (Search Sector)	Contrast Difference for Detection
0.	.02
1.75	.027
9.75	.077
11.75	.268
21.17	1.000

THERMAL SIGHT SPECIFICATIONS FOR TUGV MODEL	
Narrow Field of View	5.0 Degrees
Wide Field of View	5.0 Degrees
Cycles per Milliradian (Search Sector)	Temperature Difference for Detection
0.	.01
1.225	.075
2.175	.171
3.725	.330
5.0	1.12

The probability of hit and probability of kill against the model TUGV are given in Cersovsky and Kleinschmidt [1].

6 Sound Algorithm

We open this section by describing factors that can affect the speed of sound in the atmosphere, for more details see e.g. Cersovsky and Kleinschmidt [1] or Sen [7].

It can be shown that pressure has no effect on the TUGV's acoustic system.

The speed of sound is directly proportional to the square root of the absolute temperature. This factor was taken into account in the sound algorithm BNOISE (Sen [7], p. 125).

The increase in humidity lowers the density of air and thus increasing the speed of sound. The relationship given in [7] is

$$\frac{v_d}{v_m} = \sqrt{\frac{\rho_m}{\rho_d}}$$

where v denotes speed of sound, ρ the density and the subscripts d, m are for dry, moist air respectively. This factor was not incorporated in any previously existing algorithm.

The wind velocity should be added to the velocity of sound waves (vector addition). The algorithm we incorporated in Janus allows for downwind, upwind or neutral but no other direction. One can generalize the algorithm to other wind directions. Other factors that could be considered are topography and vegetation.

We will assume in our algorithm the following:

1. The propagation of sound is modeled as a wave front that expands in a spherical manner from the source.

2. Sound has no blind spots.

3. Friendly forces can only hear enemy forces (TUGV is in forefront and listening to region away from friendly forces).

4. Each platform is considered in isolation.

The sound algorithm is designed to detect tracked and wheeled vehicles and aircraft. The algorithm takes into account ground impedance. See Cersovsky and Kleinschmidt [1] for explanation how. In Table 5 we give the direction distances for detection of wheeled and tracked vehicles. Note that the assumption is that wheeled vehicles detection distance is 30% that for tracked vehicles.

To compensate for terrain and vegetation the data was reduced to 30%. Note that the speed of vehicles is much less than the speed of sound, and thus the distance for stationary or moving is the same.

Once a target is detected, a directional line will be displayed. The direction incorporates the circular error probability. Once the TUGV detects an enemy wheeled vehicle, tracked vehicle or helicopter acoustically, a colored line (orange, purple, green respectively) will emanate from the TUGV in the general direction of the target. If a target is detected by

Table 5:

Vehicle/wind	Non-obscured distance	Obscured distance
wheeled/upwind	.39	.273
downind	1.92	1.344
neutral	1.41	.987
tracked/upwind	1.3	.91
downwind	6.4	4.48
neutral	4.7	3.29
Helicopter/upwind	1.8	1.8
downwind	8.8	8.8
neutral	8.0	8.0

Table 6: BASELINE WEATHER

CLEAR WEATHER CONDITIONS	
Amount of Light	Daytime
Visibility	8000 m
Wind Direction	200 degrees from positive X-axis Counterclockwise
Wind Velocity	5.6 kph
Ceiling	1500 m above ground level
Relative Humidity	.95 or 95%
Temperature	75° Fahrenheit
OBSCURED WEATHER CONDITIONS	
Amount of Light	Night
Visibility	3000 m
Wind Direction	270 degrees from positive X-axis Counterclockwise
Wind Velocity	3.6 kph
Ceiling	3500 m above ground level
Relative Humidity	.70 or 70%
Temperature	53.2° Fahrenheit

Table 7:

Scenario type	Mean number of detections
With TUGV	43.900
Without TUGV	22.800
Offensive mission	12.600
Deffensive mission	54.145
Clear weather/Day	34.345
Obscured weather/Night	31.400

two or more acoustic sensors, an "A" will be displayed at the intersection of the lines. Each acoustic sensor can detect up to 100 different targets at one time. The sensor does NOT function while the TUGV is moving (since its noise will mask all other sounds) or in hold fire status. The screen display is updated every 30 seconds. A target acquired could be lost if it moves outside the listening range of a sensor. This is more realistic than in UCCATS.

The temperature dependence can also be incorporated in Janus (A) (see [2] p. 122).

7 Effectiveness of TUGV

We have designed an offensive and defensive scenarios with and without TUGV and two weather conditions. The details of the scenarios are given in Cersovsky and Kleinschmidt [1]. In Table 6, we give the weather conditions considered in our tests.

The mean number of detections for all scenarios which include the TUGV is 43.9 with standard deviation of 32.54. This is compared to mean of 22.8 and standard deviation of 12.48 without the TUGV. Thus addition of TUGV almost doubled the number of detections. In Table 7, we give the mean number of detection for each type of scenario.

Remarks: In offensive missions, the TUGV is on the move and can't detect while moving. The weather change, did not significantly affect the number of detections. The factors incorporated in the sound algorithm are: wind direction (partially), ground impedance, ambient noise level, vegetation and terrain (crude), humidity and temperature (see table 6). We would like to improve on the algorithm by refining the effects of vegetation and terrain and by including all possible wind directions. We also suggest to create an acoustic data screen in Janus so that the user can alter the sound parameters, e.g. the degree at which one target must be from another to be distinguished as a separate target (currently 15°).

8 Further Research

The second algorithm, as implemented in Janus by Cersovsky and Kleinschmidt [7], uses the subroutine ACOUSDET2 developed by TRAC White Sands [9]. Several parameters are built-in the subroutine. We suggest to have those parameters and others available for the user to modify. To this end, we suggest to have a sound screen with the following:

Parameter	Default value
Play sound	yes
Wheeled detection distance relative to tracked	30%
Percentage to compensate for vegetation & topography	30%
Humidity	70%
How close is considered same target	15°
Wind speed	3.6 $\frac{km}{h}$
Wind direction	0-60 upwind 60-120 neutral otherwise - downwind

Certainly, the subroutine ACOUSDET2 should be modified to allow for these control parameters.

Additionally, vegetation effects need to be better quantified rather than use the strict 70% degradation factor. Attenuation factors should be investigated for the various Janus vegetation codes.

Terrain poses a much more difficult problem, mainly due to the reflections off terrain features. Research using ASW (anti-submarine warfare) techniques may prove useful in describing this phenomenon.

References

1. D. Cersovsky, E. Kleinschmidt, Mathematical Model and Analysis of the Tactical Unmanned Ground Vehicle (TUGV) Using Computer Simulation, M.Sc. Thesis, Naval Postgraduate School, Department of Mathematics, Monterey, CA, June 1993.

2. D. Effland, L. Little, V. Pawlowska, Blast Noise Prediction Volume II, U.S. Army Corps of Engineers, Construction Engineering Research Laboratory Technical Report N-98, March 1981.

3. J. K. Hartman, Lecture Notes in High Resolution Combat Modelling, 1985.

4. B. O. Koopman, Search and Screening, OEG Report No. 56, Operations Evaluation Group, Navy Department, 1946.

5. B. Neta, B. Mansager, Audio Detection Algorithms, Naval Postgraduate School Technical Report, NPS-MA-92-8, Monterey, CA, 1992.

6. M. D. Proctor, JANUS (A) Basic User's Tutorial, Technical Document TRAC-RDM 92-1, TRADOC Analysis Command, Monterey, CA, 1992.

7. S. Sen, Acoustic Waves and Oscillations, Wiley Eastern Limited, New Delhi, India, 1990.

8. R. Tromel, Integrated Acoustic Sensor for Surrogate Teleoperated Vehicle, SAIC Bio-Dynamics, personal communication, 1992.

9. B. Watson, Remote Acoustic Sensor Algorithm, Janus Gaming Division, TRAC White Sands, NM, 1993.

10. S. Wong, The UCCATS Algorithms Manual, Conflict Simulation Laboratory Report, Lawrence Livermore National Laboratory, Livermore, CA, 1991.

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